Power in the Information Age

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Abstract

The assessment of capabilities and other forms of potential power has to reflect the technologies of a given historical period. The invention of nuclear weapons, for example, changed the way people thought about the distribution of power after the end of World War II. The widespread use of high-speed digital computers and telecommunications networks since the late 1960s is likely to have a similar impact on the assessment of power. This chapter focuses on the question of how one should think about power during periods of rapid technological change, and particularly the current period. It argues that there has been a shift in the conceptualization of technology as a result of the rise of information technologies. The new conceptualization emphasizes the embedding of institutional and cultural elements in information technologies and the possibility that the transfer of technologies across national boundaries will become more problematic.

Introduction

Power and technology are closely related to one another, so the assessment or measurement of power generally takes this interdependence into account. In *The Peloponnesian Wars*, for example, Thucydides was careful to tell us how many *hoplites* (armored foot soldiers) and ships each side had prior to an important battle. Similarly, after the end of World War II, most attempts to assess relative national strengths had to take into account the possession of nuclear weapons and nuclear weapons delivery systems. We want to go beyond the more limited question of assessing military power in terms of military technology to discuss the cognitive and conceptual underpinnings of power. We are interested not just in the measurement of military/strategic power of nation-states at the international level but in the factors which may be changing the distribution of all types of power within and across nations in the information age. We will focus in this essay, however, primarily on the impact of information technologies on the conceptualization of technology itself and discuss some implications of the changed conceptualization on power assessment.

It is necessary first to take a step back and ask about the relationship between information and knowledge. We assume that knowledge creation and dissemination require the analysis and restructuring of information and that information, by itself, does not constitute knowledge. In fact, too much information in the context of confusion leads to what some people call "infoglut." One must possesss some sort of cognitive filtering and structuring mechanism to sort out the relevant information from the irrelevant and to incorporate the new information productively into the old synthesis. However, without accurate and timely information, even the best conceptual structures are useless. Thus, there is an interdependency between information and knowledge, just as there is between knowledge and power. Power often enables actors to acquire both the information and conceptual tools they need to devise effective strategies; knowledge helps actors to define goals and objectives in a more informed and potentially more rational manner.

The word “technology” was first used in the seventeenth century, when it began to replace the more elementary idea of “technics.” According to the *Oxford English Dictionary*, its original English meaning, dating back to the early 17th century, was "a discourse or treatise (a *logos*) on art or the arts," or again, "the scientific study (a *logos*) of the practical or industrial arts." A second meaning identifies technology as "technical nomenclature," that is the terminology or speech -- *logos* -- of a particular art. Only in the second half of the 19th century was the meaning transformed to refer to the practical arts themselves, taken collectively: e.g., “His technology consists of weaving, cutting canoes, making rude weapons.”

Etymologically, the term "technology" has the Greek root *techne*, or art, meaning especially the useful crafts rather than the fine arts, that is, carpentry and shoemaking rather than poetry and dance; and *logos*, articulate speech or discursive reason. But the Greeks did not know the compound, *technologos*. The closest they came to any such notion would have had the emphasis reversed: not an account about art (a *logos* of *techne*) but an art of speaking. Rhetoric, the art of persuasive speech, was indeed a *techne* of *logos*, and in the view of the sophists, a means of rationalizing political life free of the need for force [Melzer 1993, p. 3].

Knowledge power, according to Francis Bacon, was the aim of science to discover “the knowledge of Causes, and secret motions of things; and the enlarging of the bounds of Human Empire, to the effecting of all things possible.” [Bacon, 1624, p. 36] This was a succinct, confident and ambitious statement of the nature and purpose of science; it brought together the previously separated notions of scientific knowledge, power, and progress. Bacon presented two new aims of academic work: “control of nature” by means of science and “advancement of learning.” Bacon wanted scientists to pursue progress rather than individual fame, to cooperate with one another in order to bring about the speedier progress of civilization. Neither disputing scholastics nor literati, greedy of glory, were scientists in Bacon’s conception. Whereas previously knowledge had been considered an end in itself, and the quiet contemplation of truth the highest vocation to which man could aspire, Bacon believed that the end of man was action and the end of knowledge utility. This is why some philosophers consider Bacon to be an early exponent of utilitarianism.

Since Bacon's time, the scientific/technological project, exemplified by the academic study of the natural sciences and engineering, has triumphed. Most contemporary governmental R&D programs share the premises in Bacon's writings, that science and technology is for the betterment of the human condition, in general, but also for the advancement of the interests of the nation-state in which technology is invented. Bacon's idea of knowledge power is, therefore, a useful place to start in attempting to understand power in the information age. But Bacon's formulation needs some updating to take into account changes in the nature of the processes by which knowledge is created and embedded in technology, especially since the beginning of the information age, and the ensuing shifts in the conceptualization of technology and technological knowledge.

Toward a New Conceptualization of Technology

We have inherited many conceptual tools from the past which are not adequate for understanding the various social transformations caused by these important technological changes. Although we have witnessed the rise of a number of new terminologies for describing social transformations influence by technological change since the 1950s -- such as the post-industrial society, post-Fordism, post-capitalist society, information society, knowledge society, information revolution, microelectronics revolution, the Third Wave, and post-modern society -- these concepts do not, in our view, capture the essence of the changes we have been experiencing. We think the best way to proceed is to characterize as accurately as possible the impact of modern information and communications technologies on the conceptualization of technology itself.

Technology has often been understood as "hardware:" e.g., a weapon, a production facility, or a piece of telecommunications equipment. For differentiating the conceptual structure of technology, however, we should note that technology, like Janus, has two faces: the "hardware face (material product)," and the "software face (technological knowledge)." Most technology is not merely a material product nor merely technological knowledge, but usually a combination of both. Hardware is useless without the knowledge of how to use it. Moreover, technological knowledge alone often has no utility until it is embodied in tools, instruments, or machines. The hardware face of technology is generally easier to grasp, because of its tangibility, which is why we tend to think about technology in terms of hardware only.

Technology is "the systematic application of scientific or other organized knowledge to practical tasks by ordered systems that involve people, organizations, living things, and machines." [Pacey 1983, pp. 4-7] Technology has four aspects: machines, knowledge, organizations, and people. This paper identifies four related aspects of technology that have unique policy implications for technological development: material products, knowledge, institutions, and culture. Only the first two aspects of technology are included in the "restricted" meaning of technology. In order to grasp the whole picture, however, we also need an "extended" meaning of the concept which includes all four aspects. In the restricted meaning of technology, the adoption of new technologies is a purely pragmatic affair and has nothing to do with the possible impact of technology on institutions and culture. In the extended meaning of technology, technology policy is closely related to an assessment of the impact of new technologies on social institutions and culture.

[Insert Figure 1 about here]

We know from empirical study of the process of technological adaptation and diffusion that technological change does not take place in isolation from institutional and cultural considerations. Institutional and cultural factors have an important impact on the development and diffusion of new technologies. To some extent, each new technology "encodes" a set institutional and cultural practices in itself as part of the process of being accepted in different societies. That is why countries that are trying to "catch up" technologically often get involved in intense internal debates about which technologies to pursue and how to reconcile these technologies with their culture and institutions.

A good example of this is the recent debate in Asia about how to deal with the Internet. Many countries are uncomfortable with permitting their citizens to gain access to a communications medium that can be monitored and censored by a central government only with great difficulty and possibly at the expense of reducing the value of introducing the new medium. Similarly, many countries are concerned about controlling the content of television programs transmitted globally via direct broadcast satellites. There is both the normatively dubious concern on the part of authoritarian governments of losing their ability to control access to important sources of information and the somewhat more legitimate concern of governments to protect their citizens from exposure to the pornography and violent messages that are carried on both the Internet and satellite television.

Figure 1 above implies that technology is like an iceberg -- with a visible part above the water line and an invisible part below the surface. The visible part of technology is often embodied in hardware; the invisible in supporting “software” including the knowledge that made the technology possible in the first place. The conceptual core of technology is the knowledge aspect, “the semi-visible part.” The emphasis on visible vs. invisible elements of technology may depend upon the conceptualization of technology in a particular society or culture. For example, the emphasis was different in China and Japan in the 19th century. The Chinese were relatively hardware-oriented -- focusing on the visible tips of the iceberg of technology, and so were not willing to pay attention to the invisible part of Western technology, in particular, at the early stage of modernization. In contrast, the Japanese were willing to accept the invisible as well as the visible part of Western technology. This is the point from which Chinese and Japanese responses sharply diverged at the early stages of their modernization. This divergence of conceptualization may be found in every aspect of their modernization processes. [Kim 1995]

An important aspect of technological knowledge in the information age is frequently human-embodied knowledge. This is the technological knowledge embodied in the creators or users of technology rather than in software or hardware. It is sometimes called “tacit knowledge,” or “uncodifiable knowledge” and is closely related to the creation and learning processes associated with the development and diffusion of new technologies. Generally speaking, the more complex the technology is, the more time and effort required to train a human to use it, and hence the higher is the degree of human-embodiment of technological knowledge. When technological knowledge is tacit or uncodifiable, technological development is likely to be more dependent on historically determined skills and search routines. Technology often cannot be easily transferred because of its dependence on the local, specific competence of individuals. An example would be the failure of many attempts around the world to establish copies of the Silicon Valley of Northern California. Obviously, there have been some limited successes, but none duplicates the size and breadth of activity to be found in the original site.

There are three further characteristics of technological knowledge that are worthy of mention here: appropriability, codifiability, and shareability (or compatibility). Appropriability deals with the credibility and enforceability of claims of ownership, codifiability with the ability of people to write down in some reproducible form the essence of a technology, and shareability with the possibility of transferring usage rights for the technology easily and quickly.

Paul Krugman (1987) has put forward three types of appropriability of technological knowledge: a) largely appropriable knowledge, such as production process knowledge reflected in firm-specific learning curves, which can be internalized within a firm and is therefore largely appropriable; b) semi-appropriable knowledge of product design that once generated can often be captured by competitors through "reverse engineering;" and c) spreadable (footloose) and non-appropriable knowledge that spreads beyond the innovating firm but not necessarily easily beyond national or sometimes even regional boundaries. This is often embodied in people and spread through social and academic networks. The ability of firms or nations to reverse engineer the technologies developed elsewhere speeds the international diffusion of technologies, but at some cost. Obviously, both the speed and expense of copying others' technologies is lower for spreadable technologies than for appropriable technologies.

For national governments, there is an interesting tension between the desire to promote the development of spreadable technologies in the public interest and in promoting the development of largely appropriable technologies as a way of creating at least short-term advantages for domestic private industry and for military capability. Each major industrialized government recognizes this tension by dividing bureacratic responsibility for the funding of basic and applied research among different agencies. Basic research funding is generally administed by Ministries of Education and Research and generally is spent by universities and government laboratories often in the form of outright grants. Applied research funding is generally administered by Ministries of Commerce, Industry, and Defense and generally is spent by private firms under contract to the government. Similarly almost all governments recognize the desire of private actors to appropriate new technologies and exploit them for financial gain in order to encourage technological innovation. They do this primarily through intellectual property protection: patents, copyrights, etc. [Long 1991] This raises the question of the extent to which a given technology can be codified so that it can qualify for intellectual property protection.

There are three main types of codifiability of technological knowledge: a) non- or semi-codifiability in largely appropriable knowledge; b) codifiability in semi-appropriable knowledge; and c) non-appropriable knowledge. Clearly codifiability and appropriability are related in that an uncodifiable technology is more difficult to appropriate than a codifiable one. One of the more important features of the information age is the effort being made to codify many previously uncodified human practices via electronic hardware and software. Thus, for example, it is not unusual to find filtering programs for your email software that help you weed out unwanted messages from untrusted sources. The software, sometimes called an "intelligent agent," learns how to do this by observing your own filering behavior. Not so long ago, a secretary had to do this for you (or you did it yourself) and the filtering knowledge was human-embodied and not codified. After the filtering agent does its job, that knowledge is software-embodied in your computer hardware and codified.

The increasing trend toward codifying knowledge in software has raised the salience of intellectual property laws and enforcement in the eyes of national governments. In order to promote the software industry as part of the larger task of promoting the computer industry, many governments of advanced industrialized nations grant temporary monopoly privileges to the writers of new software through patent and copyright laws. The patent and licensing fees paid to firms that sell the software are used to compensate them for the expense of developing the software in the first place. However, software is relatively easy to pirate (via the selling of illegal copies) and so software firms frequently turn to their home governments to help them enforce their intellectual property rights at home and abroad.

It is often not in the interest of the less industrialized countries to vigorously cooperate with the intellectual property regimes established by the industrialized countries because those regimes force them to pay a premium for new technologies that are largely invented abroad. If they can use the technologies by copying them illegally and therefore enjoy much lower prices, then generally they will do so. However, there are two main costs associated with this practice. First, if the country condoning piracy wants to develop its own domestic software industry, it will be strongly handicapped in doing so because of lax or nonexistent enforcement of intellectual property rights. Second, the firms controlling the development of valuable intellectual property, many of which are multinational enterprises, may be less willing to sell their most advanced products in countries that do not enforce intellectual property laws because of the low likelihood of making a reasonable profit. So the country that chooses this path may be excluding itself from the benefits of the latest innovations in hardware or software.

Shareability is particularly important for technologies which become more useful to humans to the extent that they are widely shared. A good example would a telegraph or telephone network. Network infrastructures become more and more valuable to their users as the number of people who can be reached via the network increases. Economists call this *network externality*. Languages work this way also. The more people who share a given language, the greater the usefulness (at least in theory) for the people who use the language. If a technology is hard to use, if it is priced unreasonably, or if ownership rights are difficult to guarantee, then shareability problems might crop up. A technology which is easily transmitted via existing transportation and telecommunications networks is potentially more shareable than one which cannot be diffused in that manner. The software side of information technology is particularly high on shareability, especially via the relatively new high-speed telecommunications networks currently being built. By the same token, however, that technology may be difficult to appropriate because of the ease with which it can be pirated via illegal copying and transmission over the network.

The Evolution of the Concept of Technology

To conceptualize the current transformation of technology, we need to understand the origin of the concept and its historical evolution. What is the modern concept of technology? What are the differences between the modern and pre-modern technologies? Are there any mid-range or micro-level changes in the concept of technology in any given era? To answer these questions, we need to explore the conceptual history of technology at the following three levels: 1) technology as hardware, 2) technology as knowledge, and 3) technology as institutionally and culturally embedded knowledge.

Hardware invention been developed in four stages: the primitive, the pre-modern, the modern, and the information society (see Figure 2). There are three criteria to distinguish them: intention of invention, linkage to specific persons, and knowledge application. In primitive society, invention is just a discovery with no human intention for invention. In pre-modern society, invention is the intentional making of "tools." Invention does not yet include the invention of "machines." Tools are regarded as an extension of the craftsman's hands. The tools cannot be understood separately from the craftsmen themselves.

[Insert Figure 2 about here]

In the modern world, invention becomes the making of a machine which is active rather than passive, which acts directly on the object being worked albeit still under the command of a human operator. The man is master of the machine, but unlike the craftsman's tools the machine makes its own demands on its operator and the organization that buys and operates the machines (which is usually not the same as the worker) may impose further strictures on the worker's behavior.

In the information age, invention becomes the making of intelligent (or at least programmable) machines with far greater autonomy from their human users than the machines of the modern era. Intelligent machines require software as well as hardware. The intelligent machine of the information age becomes more like a “co-worker” or “assistant” than the machines of the modern era.

Technology has implications for the destructive, productive, and communicative potential of human societies. Technological innovations tend to co-evolve in the three sectors (see Figure 2). We are especially interested in the overlap between military (destructive) and industrial (productive) technologies, referred to in recent times as the issues of spinoff, spin-on, and the promotion of dual-use (military and civilian) technologies. [Vogel 1992] Furthermore, we might think further about triple-use technologies that have military, industrial, and communicative implications simultaneously. This tendency of technologies to overlap may be an important and possibly distinctive feature of technological knowledge in the information age, but clearly such overlaps existed in earlier times as well.

Of the many things written on the concept of technology as knowledge, the work of José Ortega y Gasset (1972) is probably the most famous. Ortega y Gasset outlines the evolution of technology, dividing it into three main periods: the technics of chance, the technics of the craftsman, and the technics of the technicians. The difference between the three is in the way one discovers the means to realize the project one has chosen -- that is, in the "technicity" of technical thinking. We are extending Ortega y Gasset’s categorization by adding the technics of the information worker (see Figure 3).

[Insert Figure 3 about here]

The Technics of Chance: In the first period, there are no methods or technics at all, and a technic must be discovered simply by chance. Technics are regarded as a part of nature. An accidental revealment of nature are technics. Technics belong to the sphere of probability. Technics are part of the mystery of the nature. Strictly speaking, this is still a pre-technological concept of technics.

The Technics of the Craftsman: In the second period, certain kinds of technics have become conscious and are passed from one generation to the next by a special class of individuals, the artisans. Still there is no systematic study of technics that can be called technology. A technic of this period is simply a skill, an art, or a craft embedded in individual, not scientific or systematic (i.e., socially shared), knowledge. The “technics of planning” are not separated from the “technics of practice” as they are to become in the modern era. A craftsman is a technician as well as a worker. In order to acquire the technics of the craftsman, a person must enter one of the exclusive communities of craftsman (e.g., a guild or a workshop), and accumulate experiences within that community. These technics cannot be explained by words or writings alone, but only by training. The aspiring artisan must learn in a long apprenticeship. There may be no concept of “progress” among craftsmen even though there is usually an idea of “virtuosity.” Most of the pre-modern Oriental technics belong in this category, and most western technics before the Industrial Revolution also belong to this category.

The Technics of the Technician: It is only in the third period, with the development of the analytic way of thinking associated with the rise of modern science, that the technics of the technician or engineer -- scientific technics, "technology" in the literal sense -- comes into existence. The great document of this dramatic shift from skill to technology was the *Encylopédie,* edited btween 1751 and 1772 by Dennis Diderot and Jean D’Alembert. This famous work attempted to bring together in an organized and systematic form the knowledge of all crafts is such a way that the non-apprentice could learn to be a “technician.” In this period, discovering the technical means for realizing any end itself becomes a self-conscious scientific discipline. The "technicity" of modern technics is radically different from that which inspired all previous technics in that it manifests itself both in technics and in scientific theory. In our time, as Ortega y Gasset puts it, humanity has "the technology" before "a technics." People can know how to realize any project they might choose even before they choose some particular project. Technology becomes a system of knowledge emancipated from nature and specific human beings.

The Technics of the Information Worker: In the continuum of the above categorization, we would like to introduce the idea of the technics of information workers and a new term, *technoledge*, a compound word from technology and knowledge, to represent the new meaning of technology in the information age. We hypothesize that another fundamental transformation of the concept of technology is occurring with the introduction of new information technologies, especially computer software and telecommunications technology, into the process of technical innovation. The "technicity" of the current technics is radically different from that of previous technics. People now can know how to realize any project they might choose even before they choose some particular project, as before, but now they have the knowledge of how to take a general system or approach and apply it flexibly to solve a problem for a specific user of that technology. Therefore, technoledge combines knowledge about machines with knowledge about the humans using the machines. In the information age, therefore, technological discourse has to become much more open to participation by the users of technology (often the general public) and includes many factors previously excluded in the earlier and narrower discourse among technologists. Both diversity and universality are the goals of technological activity in the information age.

The Fit Between Pre-Existing Institutions and New Technologies

Since the modern concept of technology has emerged, technologies and institutions have tended more and more to co-evolve. That is why it is increasingly important to understand the embedding of cultural and institutional elements in new technologies. One issue that is raised by the discussion above is that of the ease with which new information technologies can be adapted and diffused within different societies. This is obviously important if -- as we assume -- power, like international economic competitiveness, depends on the rapid adaptation and diffusion of new technologies. Since the new technology embeds cultural and institutional practices into the technology itself, there may be new types of impediments to the transfer of these technologies across national boundaries that did not exist in earlier periods.

There are two literatures that can provide some purchase on this issue. The first deals with the major differences in institutional arrangements among the major industrialized countries and relates those differences to important economic outcomes. The second deals with the possible institutional requisites of the new technologies. We will summarize these literatures by focusing on only two works. [Hart 1992; Kitschelt 1991]

Which types of state-societal arrangements are conducive to the diffusion of new technologies? In *Rival Capitalists*, the crucial issue is the relative power of government, business, and labor (see Figure 4). The five countries in Hart's study divide into two groups: (1) dominance of one factor and (2) and the sharing of power of two factors. The three factor-dominant patterns are either government-centered, business-centered, or labor-centered. France, the United States, and Britain belong in the factor dominance category: with strong government in France, strong business in the United States, and strong labor in Britain. Shared power patterns consist of three types: government and business, government and labor, and business and labor. Japan and Germany belong to the shared power category: with a coalition of strong government and strong business in Japan, and a coalition of strong business and strong labor in Germany.

[Insert Figure 4 about here]

Based on his empirical study, Hart argues that countries with shared power have experienced increased competitiveness in the last two decades relative to countries with factor dominance. Shared power arrangements are more flexible in that they provide a favorable environment for the rapid introduction of technological innovations. Countries with factor dominance are relatively less flexible because the dominated factors resist technological change. The competitiveness of Britain and the United States in major industries, such as steel, automobiles, and semiconductors, has declined; the competitiveness of Germany and Japan in those industries has increased; and France's performance has been somewhere in between.

Can these results be generalized to all types of technologies? Hart raises this question in discussing variations within countries. For example, while German industry becomes more internationally competitive overall in the 1980s and 1990s, it remains considerably weaker than the United States and Japan in high technology electronics. Similarly, Japan seems to have had trouble catching up with the United States in microprocessors and software technology. So the question arises as to whether there is a set of desirable institutional arrangements that are specific to a given technology.

Herbert Kitschelt argues that any technology has two important dimensions: coupling and complexity. First, according to Kitschelt, we have to distinguish whether the elements of a technological system are loosely or tightly coupled. The extent of coupling refers to the requirement for spatial or temporal links between different production steps. If the steps must be done at the same location or at the same time, they are tightly coupled. But, if they can be done in any sequence at any location, they are loosely coupled. In loosely coupled systems, each step or component of production is separated from every other step in space and time. Tight coupling requires close supervision in order to contain problems that might otherwise spread quickly to other processes, and loose coupling permits less centralized control. The tighter technological elements are coupled, the more control needs to be centralized. This concept of coupling is closely related to the level of capital investment and to the size of the economy. If a technological system is tightly-coupled, it generally requires a large economy with high levels of capital investment for local firms to be successful. However, if the technological system is loosely-coupled, it is does not require a large economy or high levels of capital investment for local firms to be successful.

Second, we have to consider the complexity of causal interactions among production stages. Complexity refers to the importance of feedback among production stages that is required to keep the whole process on track. Linear systems that proceed from one stage to the next without feedback are not complex, but those that are iterative and interactive are more complex. Complex systems have large information requirements to manage the intricate flow of connections across processes, but large communications flows can overload the capacity of centralized governance structures. As a result, complex systems favor decentralized production units coordinated through network connections. Technological processes that are more sequential, and less interactive, have fewer information requirements and are therefore more amenable to centralized control. If the technology is not complex, then its trajectories are predictable and production advances in continuous, incremental steps. However, if the technology is complex, technological innovations have to be explored by trial and error, yielding fast-paced technological change with major breakthroughs followed by small incremental improvements.

Based on these two dimensions, Kitschelt distinguishes five technological clusters from Mark I to Mark V technology. In this essay, we are slightly modifying his categorization by reinterpreting his Mark III category and by dividing his Mark V into two distinct technological clusters, creating six types in all. Like Kitschelt, we hypothesize that each technology requires a distinct governance structure for its maximum performance. Although the combination of coupling and complexity of a technology do not determine a uniquely optimal governance structure, they do constrain the efficient possibilities. The possible efficient governance structures or the favored institutional arrangements from Type 1 to Type 5b are as follows.

[Insert Figure 5 about here]

Type 1 Technology (1770-1840): This is a loosely-coupled technological system with linear interaction among its components. Concentrated ownership is not necessary, nor are there important economies of scale. Because knowledge intensity is quite low, technological trajectories in this case are readily predictable. Therefore, new technologies are incrementally innovated. Consumer goods, light machine tools, and textiles belong to this type. In the case of Type 1 technology, a decentralized, market-oriented system with weak government and strong business can exploit most energetically the opportunities offered by the new technological trajectory. Innovation in these systems stems from the incremental process of "learning by doing," rather than systematic research organization.

Type 2 Technology (1830-1890): This is a tightly-coupled technological system with linear causal complexity. Because knowledge intensity remains fairly low, its product advance is still made incrementally along predictable trajectories. But, this type of technology requires large capital investments, and economies of scale increase rapidly. The heavy industries, such as iron/steel and railroads, belong to this type. In the case of Type 2 technology, the efficient governance structures shift from small to large corporations, from competitive to oligopolistic markets. The domestic structures that succeed in innovations are business-oriented arrangements which facilitate industrial centralization, however, incremental innovations are primarily propelled by large corporations through systematic research in private laboratories. In the late industrializing countries, the state-societal arrangements where government is deeply involved during industrial development also fit this technological type.

Type 3 Technology (1880- 1940): This is a highly to moderately coupled technological system with low to moderate causal complexity. This type of technological system involves moderate knowledge intensity, and the technological trajectories are readily predictable. So, its product advancements are made incrementally. But, the capital requirements are relatively high, and the economies of scale are quite large. Chemical production, electrical engineering, consumer-durable-goods, and automobiles fit into this type. In the case of Type 3 technology, centralized institutional arrangements are required to develop this type of technology, especially, in monopolistic markets. Historically, this technology has involved in the production of "Fordist" mass-produced consumer goods, which fostered the emergence of large multinational corporations.

Type 4 Technology (1930-1980): This is a tightly-coupled technological system with high causal complexity. Because this type of technology requires intensive knowledge, the trajectory is quite unpredictable. The advancement of its product are made by leaps, not incrementally. The scale of economy is very large, and investment risks are very high. Representatives of this type include nuclear power and aerospace. In the case of Type 4 technology, it is appropriate to have highly centralized governance structures, which put the burden of investment risks on public agencies, even in cases where the technologies would be developed or produced in privately owned facilities. Historically, two types of countries excelled in these technologies: countries that had already developed centralized state capabilities in economic governance before the new technologies surfaced and countries that acquired such capabilities in connection with the military competition of World War II and the ensuing Cold War. Thus, while the victors of World War II all ventured into the development of these Type 4 "state technologies," the losers and small neutral countries were forced to the sidelines.

Type 5a Technology (1970-): This is a low to moderately coupled technological system with high to moderate causal complexity. Because this type of technological system involves considerable knowledge intensity, the technological trajectories are not readily predictable. Product advances are made in incremental steps with some breakthroughs. The economies of scale are initially moderate but increase over time. An example is a type of integrated circuit, the Dynamic Random Access Memory (DRAM). DRAMs are used in computers and now increasingly in consumer electronics. In the case of Type 5a technology, countries with power-sharing institutions are better able to take advantage of these conditions. Cooperative networks between state-societal actors infuse an element of flexibility into production systems and reduce the risks of investing for individual firms.

Type-5b Technology (1970-): This is a loosely-coupled technological system with high causal complexity. Problem solving for this type of technology is difficult and complex. The technological trajectories are not readily predictable. The economies of scale are moderate initially but increase over time. Examples of this type of technology are computer software, microprocessors, and biotechnology. Type 5b technology requires more sophisticated institutional arrangements than other types. The technologies no longer reward the organized capabilities of highly-integrated private or state enterprises. Corresponding governance structures include mixed private and public research and development consortia and intercorporate alliances of various sorts (including international ones). However, because of the high technological uncertainties, organizational decentralization has to be combined with a certain amount of public funding to stimulate the necessary private investments.

To summarize, Hart's and Kitschelt's theories combined give us some purchase on the question of which institutional arrangements are most likely to promote technological innovation for different types of technologies. One question that remains unanswered is whether the institutional arrangements that already exist in various countries can be changed as needed so as to pave the way for innovative successes. We refer the reader tothe theory of “technological paradigms.” [Freeman 1987; Dosi et al., eds. 1988] This theory asserts that the relatively infrequent changes in technological paradigms require changes in products, processes, and organizations. We cannot devote more time to this question here, however, so we turn instead to the question of how to observe power in the information age.

Observing Power in the Information Age

There are basically three different ways of empirically observing power: 1) power as a resource, 2) power as a relationship, and 3) power as a structure. [see Hart 1976] We hypothesize that, as a result of the the growing importance of information technologies: 1) the main locus of power resources has been shifting from military, to economic, and now to informational resources, and 2) the main mechanisms for exercising power have been shifting from relational power to structural power.

“In the power as resources approach, power is measured in terms of control over a resource (potential power) which can be converted in some manner into control over others or over outcomes (actual power). These resources, also called capabilities, may be connected with measurable phenomena such as economic wealth or population.” [Hart 1989, p. 3] Realist theories of international relations and works on “geopolitics” often rely on a power as resources approach. Power is measured or assessed in terms of certain “capabilities” which are a function of control over specific types of resources: e.g., land area, population, GNP, energy production, etc.

In recent years, besides the usual set of capabilities used to measure power, technological capabilities are beginning to be viewed as power resources. An example would be the addition in the early 1990s of world production shares of semiconductors as one of the indicators monitored by the Central Intelligence Agency in its annual publication, *Handbook of*

International Economic Statististics. It is possible that future issues of that publication will contain tables on the number of server computers connected to the Internet or the number of World Wide Web sites in major countries. As information technology grows in importance in international relations, these sorts of changes in conventional power assessment are likely.

According to Alvin Toffler, the development of information technologies shifts the very basis of power from violence to wealth to knowledge; a phenomenon which he calls the "powershift." [Toffler 1990] While we do not necessarily agree with Toffler on this score, there is evidence for such a shift in the recent works of realists and students of geopolitics. A key unresolved issue for us, however, is whether it is really necessary to reconceive the inherited notion of national security, to redefine the international power game, and to resituate its players as a result of the rise of information technologies.

The new technologies clearly have had an impact both on power and on power assessment. If a country possesses high-tech communications equipment, then it can more easily access information resources. If a country has developed an information superhighway system, then citizens of the country can more easily access important information resources, and the country will have informational advantages over others that have no such system.

The information age is producing a blurring of boundaries between power resources. In the information age, there appears to be more concern than in previous eras about the importance of dual-use (military and civilian) technologies, the role of the media in society and the importance of possessing the means of projecting one's culture abroad, and the vulnerability of communications networks to disruption by hostile forces. These are not entirely new concerns, of course. Iron-clad ships were obviously also dual-use technologies, the telegraph and telegraph cables played an important role in the preservation of British hegemony in the nineteenth century, and there was obviously great concern about the integrity of radio and telegraph communications networks during both World Wars. Still, the intensity of concern has shifted in these directions to an extent that it is possible to say that there is a qualitative change.

The information age has made intangible forms of power more important. Control over knowledge, beliefs and ideas is increasingly regarded as a complement to control over tangible resources such as military forces, raw materials, and economic productive capability. In this context, the extent to which the politics of ideas complements power politics is becoming larger than before. As Susan Strange argues, "whoever is able to develop or acquire and to deny the access of others to a kind of knowledge respected and sought by others; and whoever can control the channels by which it is communicated to those given access to it, will exercise a very special kind of structural power." [Strange 1988, p.30]

Information is a flexible power resource that is less constrained by the time and the place than any other power resource. It is in many ways more fungible -- transferrable from one actor to another -- than other forms of power. It may be more like money and other economic resources than it is like military power resources in that regard. This commodification of information is not new but has accelerated with the growth of high-speed telecommunications technologies and digitalization of information. Thanks to the deployment of these new technologies it is easier to package, sell, and distribute information than ever before. [Giese 1994] However, it is necessary to repeat here that information without knowledge is not very useful and that information about technology is particularly difficult to transfer to others unless there is a firm cognitive and institutional basis for doing so. An example would be the limited utility of supplying the raw digital data from a spy satellite to a friendly country that did not have the capability of turning the data into images or did not have experts capable of interpreting the images for security purposes. Another example would be the sharing of a secret microchip design with a friendly country that had no semiconductor production facilities.

In the power as relationship approach, power is measured or assessed in terms of interactions between pairs of social actors. A has power over B when A and B have conflicting views about the desirable outcome of a specific situation but B acts as if it had adopted the preferences of A. Relational power can result either from coercion or persuasion. In a coercive power relationship, A threatens B in order to get B to act on A's preferences. In a persuasive relationship, A communicates with B in a non-threatening manner to convince B to adopt A's preferences. This sort of power is difficult to measure because it requires knowing A's and B's preferences both before and after the interaction between A and B. The relational approach to power is based on an empiricist conception of power.

With the end of the Cold War, power relationships that were previously based on bipolar enmity or alliances are being redefined to take into account the absence (with the notable exception of the People's Republic of China) of a Communist bloc. Part of that adjustment is an increased interest in avoiding the commitment of military resources in attempts to influence specific other actors in the international system. Thus, there is greater interest in economic sanctions as an alternative response to various forms of bad behavior, and we predict that sanctions involving a deprivation of access to informational resources will become another possible alternative to military threats as the information economy develops.

Joseph S. Nye's concept of "soft power" may be one way of understanding power in the information age, at least from the relational perspective. Soft power is the ability to achieve desired outcomes through attraction rather than coercion. It works by convincing others to comply with norms and institutions that produce a particular desired behavior. Soft power depends on the appeal of ideas and an actor's ability to set the agenda in ways that shape the preferences of others. If a state can legitimize its power by establishing and supporting new regimes, then it may be able to economize on its expenditure of traditional military and economic resources. [Nye 1990]

More importantly, international actors seem to be thinking more about the larger set of norms, rules, and procedures that govern the world political and economic systems now that the Cold War is over. They are, thus, more interested in exercising structural power. Susan Strange says that:

> "structural power... confers the power to decide how things shall be done, the power to shape frameworks within which states relate to each other, relate to people, or relate to corporate enterprises. The relative power of each party in a relationship is more, or less, if one party is also determining the surrounding

> structure of the relationship....What is common to all four kinds of structural power is that the possessor is able to change the range of choices open to others, without apparently putting pressure directly on them to take one decision or to make one choice rather than others. Such power is less ‘visible.’” “Today the knowledge most sought after the acquisition of relational power and to reinforce other kinds of structural power (i.e. in security matters, in production and in finance) is technology. The advanced technologies of new materials, new products, new systems of changing plants and animals, new systems of collecting, storing and retrieving information -- all these open doors to both structural power and relational power.”[Strange 1988, pp. 25-31]

Later in the same work, however, Strange says, “Structural analysis suggests that technological changes do not necessarily change power structures. They do so only if accompanied by changes in the basic belief systems which underpin or support the political and economic arrangements acceptable to society.” [Strange 1988, p.123] This is consistent with our argument above about the cultural and institutional impediments to the transfer of technology in the information age.

As we argued above, information technologies embed institutional and cultural practices into the technology itself. Thus, a certain amount of structural power is implicit in the transfer of information technologies across national boundaries. The country which is the source of key new technologies, such as microprocessors, fast digital switches, operating system software, and the like, frequently gets to impose its institutional and cultural arrangements on others. For example, Microsoft and Intel now dominate the personal computer market with the Windows operating systems on computers using Intel microprocessors. Computer companies and users in Europe and Asia have tried to compete directly with these firms but were unsuccessful and now are forced to adapt to the technological solutions that the dominant firms have imposed on them (as well as the rest of the world). This causes a certain amount of resentment and irritation that sometimes percolates up to the level of national governments. Yet it is arguably a result of the success of Microsoft and Intel in anticipating the demands of the marketplace, and also, to some extent, making concessions to overseas users so that they will buy their products even though they are not of domestic origin.

Conclusions

Technological change clearly influences the distribution of power in the international system. If a country possesses advanced technology, it can better produce military weapons and competitively manufacture civilian products. This is why politicians and business leaders pay so much attention to acquiring new technological knowledge. Historically (at least since Bacon), technological innovation has been regarded as one of the ways to make a society strong and wealthy. Success in obtaining or adapting a new technology produces winners and failure produces losers. In recent years, with the development of information technology, technological power is increasingly linked to information power in the form of what we call "technoledge."

Information-based technological power is different from earlier forms of technologically based power in a number of important ways. First it is connected with the successful creation or adaptation of new technologies which have a great deal of institutional and cultural information embedded in them. As a consequence, these new technologies do not flow across national boundaries as easily as technologies of previous eras. Second, information technologies have forced the governments of nation-states to rearticulate their internal structures to cope with the trend toward globalization of international business that has been made possible by faster and cheaper computing and telecommunications. [Douglas 1996, p. 7; Hart and Prakash 1997] Third, the development of information technology has greatly reduced the difficulty and expense of surveillance, and has given greater surveillance power both to states and to the citizens of contemporary nation-states. [Hewson 1994] The ability of the citizenry to use its new surveillance powers will depend upon its ability to force the state to permit access to information that was previously jealously guarded. It will also depend upon the creation and diffusion of new encryption technologies, which are increasingly used by commercial enterprises and private individuals, and thus are no longer so much under the control of national governments. Fourth, information technologies have created a new frontier for exploration which is somewhat analogous to the frontiers created by the harnessing of wind power for sailing ships in the age of exploration. Instead of the new frontiers being actual (territorial or geographic), they are virtual.

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Figure 1: The Conceptual Structure of Technology (A Simile of an Iceberg)

Hardware Aspect

Visible Part of Technology

Restricted Meaning of Technology

Extended Meaning of Technology

Knowledge Aspect

Invisible Part of Technology

Institutional Aspect

Cultural Aspect

Figure 2: The Evolution of Technology as Hardware

	Pre-modern Society	Modern Society				Information Society
The Meaing of Invention	invention= tool as passive hardware	invention= machine as active hardware				invention= intelligent machine
Military Technology *(land)*	sword spear/bow	gun cannon	rifle automatic gun	tank	missile nuclear weapon	laser weapons SDI
(sea)	sail ship row ship	steamship		turbine ship submarine	nuclear ship aircraft carrier	
(air)	hot air baloon			engine plane bomber	jet plane fighter	spaceship satellite/ stealth
Industrial Technology		textile	iron/steel railroad	electrics automobiles chemistry	electronics aerospace nuclear power	information industries biotechnology
Communication Technology	basic	telegraph	telephone	wireless telephone radio	satellite communications broadcasting	computer communication

Figure 3: The Evolution of Technology as Knowledge

	Primitive Society	Pre-modern Society	Modern Society	Information Society
the subject of technological behavior	the technics of chance	the technics of craftsmen	the technics of technicians	the technics of knowledge workers
the essence of technics	technics=nature (discovery-based)	technics=man (human-based)	technics=knowledge (knowledge-based)	technics=knowledge in a broad sense
the nature of technological behavior	practice =probability	practice=plan (the principle of similitude)	practice plan (beyond similitude searching for universality)	practice=planning allows for custom solutions to univeral problems

Figure 4: Types of State-Societal Arrangements

Source: Jeffrey A. Hart, *Rival Capitalists: International Competitiveness in the United States, Japan, and Western Europe*, (Ithaca: Cornell University Press, 1992), p.281

Figure 5: Types of Technology

high	Type 2		Type 4
		Type 3	
Level of Coupling		Type 5a	
low	Type 1		Type 5b
	low	Level of Complexity	high

Sources: Herbert Kitschelt, "Industrial Governance Structure, Innovation Strategies, and the case of Japan: Sectoral or Cross-national Comparative Analysis?" *International Organization*, 45(4), (Autumn, 1991), pp.468-475; James R.Golden, *Economic and National Strategy in the Information Age: Global Networks, Technology Policy, and Cooperative Competition* (Westport, Connecticut: Praeger, 1994) p.129